Deviating from the line

A Beautiful Mind
by Sylvia Nasar
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Karl Sigmund

In 1994, John Forbes Nash Jr received the Nobel Prize in Economics for a one-page note published in 1950. It introduced what today is called the Nash equilibrium, arguably the most basic concept, not just for game theory, but for every model of a social situation where the consequences, for each agent involved, depend not only on their own actions but also on those of the others. In a Nash equilibrium, none of the 'players' has an incentive to change strategy as long as the other players keep to theirs.

Game theory, with its stated ambition to address economic interactions of interdependent decision-makers, had been founded by John von Neumann and Oskar Morgenstern. In 1948, the second edition of their monumental book *Theory of Games and Economic Behavior* (Princeton University Press) dominated and in fact circumscribed the field: utility theory, zero-sum games, coalitions ... The 20-year-old Nash, whose education in economics consisted of one undergraduate course, had some ideas which, as he mentioned in his Nobel autobiography, "deviated somewhat from the 'line' [as in party political line] of von Neumann and Morgenstern's book".

Von Neumann was bluntly dismissive of the young man: "This is trivial, you know. That's just a fixed-point theorem." And, in a way, von Neumann was right. On the other hand, his own celebrated maximin theorem reduces to a simple corollary of Nash's existence proof, and is valid for two-person zero-sum games only; these include plenty of parlour games, but cover painfully few instances of real economic interactions. Nash's "rival approach" has incontestably won the day.

Classics in Game Theory, edited by Harold Kuhn (Princeton University Press, 1996), begins with three papers written by Nash before he was 25. With masterful poise and lucidity, they redefined the field by introducing Nash equilibria, the Nash solution of the bargaining problem and the 'Nash program' relating cooperative and non-cooperative game theory (for example, basing coalitions on negotiations).

In the following 50 years, the subject expanded enormously, but with hindsight it can be seen that half-sentences in his unpublished PhD thesis and footnotes "attributed to Dr Nash" had anticipated recent developments in some of the most active areas, like experimental economics and evolutionary game theory. For instance, the classical interpretation of a Nash equilibrium relies on the rationality of the players, who ought to be able to deduce a solution consistent with their diverse interests (she thinks that I think that she thinks ...); but Nash also proposed a "mass action" interpretation, based "on a large population of players using empirical information to arrive at a stable frequency distribution of strategies". Many years later, this approach, which dispenses with rationality, was rediscovered by theoretical biologists and led to the concepts of unbeatable strategy (William D. Hamilton) and evolutionarily stable strategy (John Maynard Smith) which dominate current thinking on adaptation by natural selection and percolate through the social sciences.

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A journey of sadness and grandeur: Nash's prime years were devastated by schizophrenia.

Fundamental as Nash's economic insights were, they used only 'easy' mathematics — what von Neumann had called trivial. This may have been the reason Nash turned away from game theory and attacked some of the technically hardest mathematical problems. He showed, in particular, that every Riemannian manifold (a curved space which looks, to any near-sighted inhabitant, like Euclidean space) could be smoothly embedded, without altering any distances, in a much higher-dimensional Euclidean space.

Nash also obtained basic results on the existence, uniqueness and continuity of solutions to nonlinear partial differential equations — equations of supreme importance to applied mathematics (fluid dynamics, for instance, and electromagnetic fields). In each case, he overcame staggering difficulties by relentlessly pushing ahead along completely unexpected lines.

This work might well have earned him a Fields medal (the mathematical equivalent of the Nobel, but restricted to people under 40 years old). By the time Nash was 28, it seemed only a matter of time: his reputation for brilliance was solidly established. *Fortune* magazine featured him as "one of the brightest new stars in New Maths". Here was a most unusual young man, tall and aloof, with strikingly good looks, married to a smart, beautiful woman.

Schizophrenia usually strikes at a younger age. In Nash's case, earlier symptoms may have been attributed to the eccentricities to be expected of a genius, the passing effects of fierce concentration and mental strain, or the arrogant self-absorption of an immature wunderkind. But slowly it became clear that Nash was sinking into a state of paranoid delusion. He gave up his faculty position at the Massachusetts Institute of Technology, and attempted to become a political refugee in Europe. "I started to think that I was a man of great religious importance ... I began to hear something like telephone calls in my head, from people opposed to my ideas ... The delirium was like a dream from which I never seemed to awake."

With the exception of a brief remission in the mid-1960s, during which Nash resumed first-class work on fluid dynamics and singularities, "an interlude of, as it were, enforced rationality", his prime years were devastated by the terrible illness. After several involuntary hospitalizations, Nash eventually drifted back to Princeton, a tragic, silent shell of his former self, haunting the campus as the "Phantom of Fine Hall", searching for secret meanings in numbers and leaving bizarre messages on blackboards.

But, "gradually, I began to intellectually reject some of the delusionally influenced lines of thinking which had been characteristic of my orientation". In the 1980s, Nash, who had resumed his life with his ex-wife Alicia, managed to recover from an illness that had been deemed incurable, and to return to scientific work. In his autobiographical note, Nash defiantly grounds his "hopes of [still] being able to achieve something of value" on having gone through "a sort of vacation", namely "the gap period of 25 years of partially deluded thinking". The enthusiastic support from a new generation of game theorists — Jörgen Weibull and

Ariel Rubinstein, in particular — helped to pave the way for the Nobel prize, a belated tribute to one of the most influential intellectual figures of our time.

This story, a modern-day version of the biblical legend of Job, is bound to attract biographers. Sylvia Nasar, an economics correspondent from the *New York Times*, was offered a visiting position at Princeton's Institute for Advanced Study to prepare her book. Her excursions into mathematics are kept to a minimum, and make little pretence at explaining Nash's discoveries. She attempts to describe the Klein bottle (a one-sided surface) without offering a figure, and does not bother to draw the board of Hex, a clever game invented by Nash as a graduate student. Her book does not provide many details on the illness either. In addition, Nash chose not to cooperate with his biographer — the arrests, deportations and enforced commitments must have been too agonizing to retrace.

Despite these disadvantages, Nasar has succeeded in writing an admirable book that grips from beginning to end. Based on hundreds of interviews, her depiction of the small tribe of top mathematicians is uncannily true to life, a masterpiece of oral history; and her inside reports from the offices of the RAND corporation ("thinking the unthinkable") or the conclaves of the Swedish Academy of Sciences are gems of investigative journalism. Most importantly, her sober, honest and humane portrayal of Nash is an absorbing experience, and fully conveys the sadness and grandeur of his fate. □

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• *A Beautiful Mind* was short-listed for the Rhône-Poulenc Prize for Science Books (see *Nature* **399**, 654; 1999).

When ideas become tollbooths

Owning the Future
by Seth Shulman
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A. P. Simonds

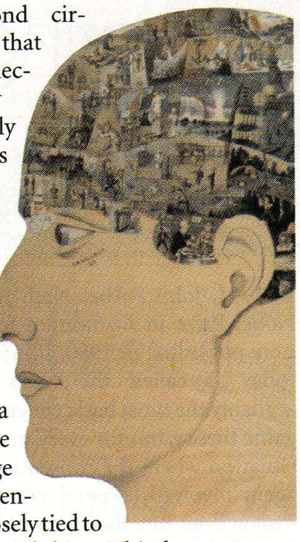
There was a time when the phrases 'marketplace of ideas' and 'free flow of information' were considered closely connected, if not synonymous. But the trends surveyed by science journalist Seth Shulman suggest that, as these phrases turn from metaphor to literal description, their mutual antagonism becomes unavoidably apparent. At the end of the day, the wedding of business and knowledge may be captured by the blunt aphorism: there's no such thing as a free lunch.

The new landscape of intellectual property has attracted wide attention, and not just from law firms, research labs and application-development shops. A contentious literature flows out of every corner of academia, from business schools to English departments. Yet, ironically, the subject has scarcely risen to the point of visibility in the national policy debates of most industrial democracies.

Beneficiaries of strong patent protection frequently present themselves as free-market individualists. Shulman describes an eye surgeon who had acquired a patent on a procedure discovered by accident and essentially similar to techniques already used by others. The surgeon defended his claim to payment of thousands of dollars in annual royalties from every other surgeon performing the procedure by noting that, after all, "medicine is a capitalist endeavour".

Yet patent protection derives not from a private right to property but from the power of the state to grant monopoly privileges on the grounds that the public's interest in "the Progress of Science and useful Arts" (to use the language of the US Constitution) overrides the individual's right to practise his trade unfettered by government constraint. Defining the nature, extent and validity of that public interest is surely essential to the business of a democratic polity.

Shulman seeks to stimulate this debate by describing a series of striking and, at least on their legal surface, egregiously expansive claims to patent protection for software routines, hybridized or recombinant organisms, and natural genetic resources. Two features of the late twentieth-century environment (rather than a simple rise in greed and incompetence) appear chiefly responsible for the observed trends. The first is that, in a knowledge-based economy, incentives to aggressively pursue and defend the broadest possible patent protection are more powerful than ever before. This is partly because personal and national wealth depends, to a far greater extent than previously, on the control of knowledge resources. But it is also the result of a classic collective-action dilemma: each company's ability to defend itself against patent claims brought by others depends, in part, on the portfolio of patents it can bring to the table in support of cross-licensing agreements. The cost of litigating these arrangements may undermine the productivity of all parties, but none of them can do anything except push forward with vigorous and expansive new claims. Shulman quotes Jonas Salk's 1954 answer to Edward R. Murrow's question about who would control the new polio vaccine: "There is no patent. Could you patent the Sun?" A half-century later, this answer would be much more difficult to sustain.



The second circumstance that makes intellectual-property claims newly problematic is evident in Shulman's selection of examples. Patent offices apply standards and criteria that derive from an age in which inventions were closely tied to discrete, material *things*. This does not mean that patenting a *process* is some novelty of the information age. (The very first patent issued in the United States was for a process used to produce potash.) But it does mean that concepts crucial to the distinction between what can and cannot, should and should not be afforded protection as intellectual property ("invention", "product of nature", "non-obvious", "language", "procedure", etc.) cannot be applied in a straightforward and unproblematic way to phenomena such as software codes, business procedures or DNA sequences.

Lawyers are quick to point out that nothing in the law authorizes ownership of an idea; all that can be protected is its "tangible expression" (copyright) or its "practical application" (patent). What Shulman shows, however, is that loopholes and ambiguities in the standards for assigning protection can and are being exploited to turn ideas into "tollbooths" that allow private appropriation of the tools of thought and which obstruct or impede the very innovation and public dispersal of knowledge that provide the public-policy justification for intellectual property in the first place.

This happens in several interrelated ways. Overly broad patents can close off competing research avenues. (Shulman offers the example of a 1994 European patent granting Agracetus exclusive rights to "any and all genetically altered soybeans", whether created by the method specified on their application *or any other*.) Abstract, essentially conceptual anticipations of devices allow a skilful ideas merchant to reap enormous licensing rewards once actual products are brought to market by others. (Schulman mentions Jerome Lemelson, awarded more US patents than anyone other than Thomas Edison, as the unchallenged master of this art.) Patents that push at the boundaries of "obvious" and "algorithm" (both non-patentable) leave programmers at constant risk of inadvertent infringement. Accidents of priority and